ADVANTAGES OF ALKALINE FUEL CELL SYSTEMS FOR MOBILE APPLICATIONS

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Advantages

Early fuel cells were built with liquid electrolytes, solutions of potassium- or sodium hydroxide or diluted acids. The classical example is the alkaline fuel cell (AFC) of Francis Bacon. The advantages of hydrogen – oxygen fuel cells for space application became clear, yet it was also the only application which could afford them. Their introduction led to the elimination of any mechanical pumps, which were not reliable enough. The use of matrices (for instance micro-porous asbestos) soaked with KOH became standard for NASA space fuel cells and is still in use, in spite of the fact that better matrices were found.

The fact that liquid circulating electrolytes offered great advantages for heat management and water removal requirements was believed to be overcome by the disadvantage of creating parasitic shunt currents in cell assemblies connected in series. Delayed start-up procedures often led to the reversal of cells and irreversible cell failures. The advantages of combining fuel cells with rechargeable batteries in a hybrid system were not recognized. As a matter of convenience and for time saving, all the testing of fuel cells was (and is) done in a continuous operation mode. The need to operate fuel cells in an interrupted fashion, with sometimes long idle periods did not seem to be important - but surely it is. The fuel cell must be able to shut down completely for longer time periods, hours, days, weeks, etc., it must be safe in the garage, with turned off gas supply, at ambient and even low temperatures. The alkaline fuel cell with circulating and removable electrolyte "does the job". It should also be mentioned that on activated stand, without load, fuel cell electrodes and catalysts degrade more than under load. The high voltage on open circuit is the reason for carbon oxidation processes, catalyst changes, etc. Unfortunately, the alkaline matrix fuel cells with immobilized KOH electrolyte combined all possible disadvantages: the electrolyte had to stay in the cells, residual carbonate (from any incomplete air-CO_2 cleaner) accumulated, separators (matrices) deteriorated, gas cross leakage started during drying out or crystallization periods during storage times without careful maintenance. Therefore it is not surprising that the AFC was disfavored [1].

The circulating electrolyte offers solutions for these problems: The exchangeability of the KOH electrolyte makes it possible to operate on air with a less than complete removal of CO_2 [2,3]. A commercial type CO_2 absorber (e.g. soda-lime) is able to fulfil this demand. Life expectancy definitely increases with circulating electrolyte by emptying the electrolyte between operating periods since this shut down eliminates all parasitic currents. No drying out occurs. Besides, an additional heat management by heat exchangers in the stack becomes unnecessary.

The competition in the automobile and the oil industry is severe and only the cost factor will finally be deciding the use of fuel cells. The use of non-noble metal catalysts in PEMFC is not likely because of the acidic pH. Alkaline fuel cells can use conventional low-cost perovskites or spinells at the air electrodes. Non-noble metal catalysts for fuel electrodes are under development. In addition, since there is no water management system, cold start capabilities are better compared to polymer electrolyte fuel cell PEFC. Considering these points, AFC might be back on the scene as soon as the fuel question is solved.

The experiences with bipolar alkaline stacks in Graz in the 1980's and the recent new emphasis on electric vehicles led to new research and a revival of the developmental work for AFCs. The research work includes modeling and construction of a laboratory vehicle. The whole system comprises the components: fuel storage, fuel cracker, alkaline fuel cell, buffer battery, system control, materials and heat management and simulation of electric load (charge, stress). Ammonia is used as fuel for the AFC at the Technical University Graz. Compared to hydrogen, ammonia offers significant advantages in cost and convenience as a vehicular fuel due to its higher density and the ease of storage and distribution. At the Technical University Graz a catalyst for cracking of ammonia into nitrogen and hydrogen was developed and a laboratory-scale ammonia cracker, providing hydrogen for approximately 1 kW was built [see 4].

Laboratory Tests

An alkaline fuel cell system (1 kW), like shown in Figure 1, is being built for the investigation of the dynamic behavior as well as for the verification of the simulation model. The fuel cell stack is being built at the Institute of Chemical Technology of Inorganic Material.

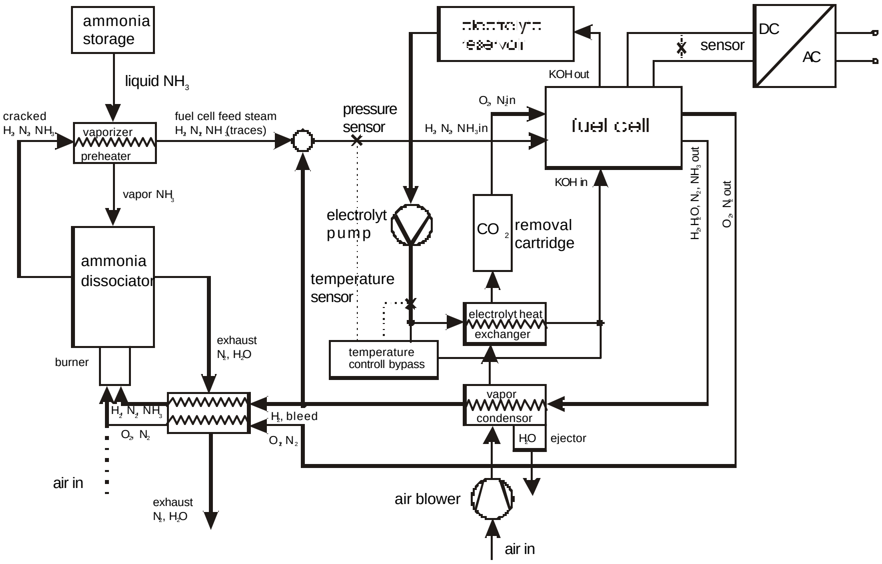

Fig. 1: Layout of ammonia/hydrogen-air fuel cell system

Manufactured electrodes have been tested in a single cell test facility. The facility consists of two gas channels for hydrogen and oxygen/air supply and between the electrodes, the electrolyte chamber for the liquid electrolyte. Due to the large distance between the electrodes the ohmic resistance in this test cell is considerably higher than in a fuel cell stack. Therefor the interruption measurement method is used [5].The reference electrode is Zinc (0) or Hg/HgO. To characterize the electrode, current/ voltage curves and current density/ polarization curves of the anode and the cathode depended on electrolyte concentration; temperature and partial pressure are measured. The hydrogen supply for the fuel cell stack is realized by an ammonia cracker. So in the loop there is always a mixture of hydrogen and nitrogen. The results of the partial pressure measurements show, that a mixture of 50/50 hydrogen/nitrogen could be used at a current load of 200mA/cm^2. Results are shown in Figure 2 and 3.

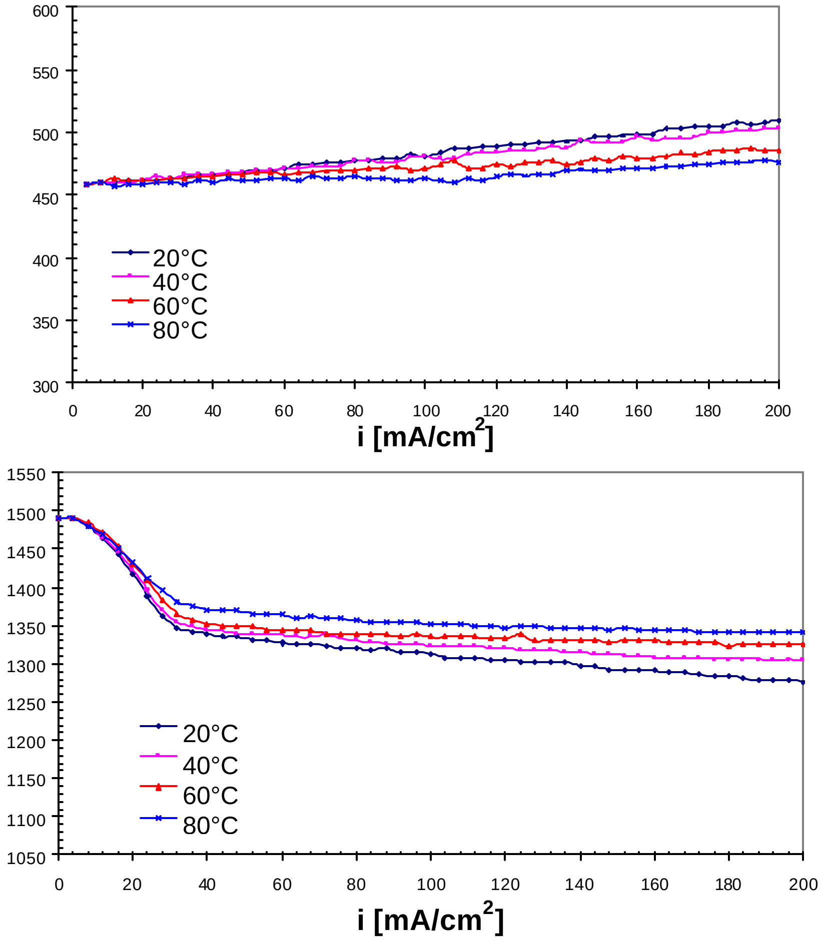

Fig. 2 Anode and cathode with 20% KOH at different temperatures

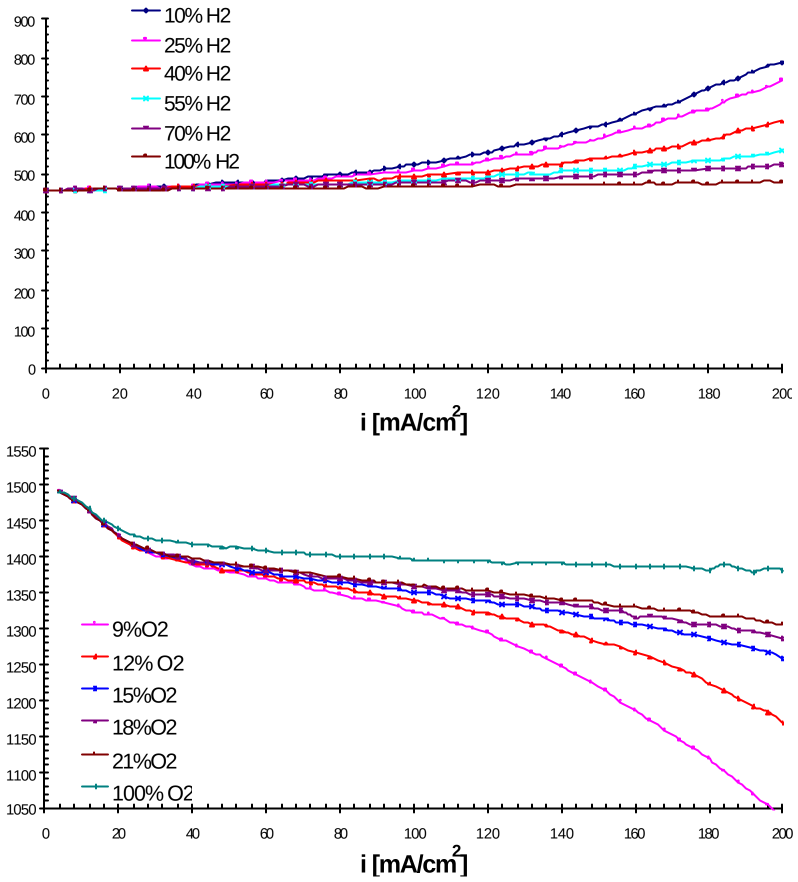

Fig.3. Anode and cathode at 80°C with 50% KOH at different partial pressure of hydrogen and oxygen

Simulation model

Much attention has been focused on fuel cell stack development. However, fuel cell power plants also include fuel processing components, ancillary components and subsystems associated with air supply, thermal management, water recovery and treatment, cabinet ventilation and system control and diagnostics. Tools for systems analysis to identify key design parameters and to validate the component's dynamic performance are becoming the focus to decide about possible design and construction for the most promising technologies [6,7]. Therefore, parallel to activities on experimental and technical development a theoretical model simulation of the AFC system including gas conditioning was worked out. For the evaluation of heat and mass transfer as well as the flow distribution of water management in AFC, an elaborated calculation model is adapted allowing considerations on an improvement of working parameters. The dynamic model enables the investigation of AFC performance under variation of load or gas supply. By means of voltage-current characteristics the influence of multiple input variables of the model such as thickness or porosity of the gas diffusion electrode or the condition of the catalytic layer can be demonstrated. Time-dependent profiles permit deductions on dynamic behavior of gas and water flows as well as of temperatures and partial pressures.

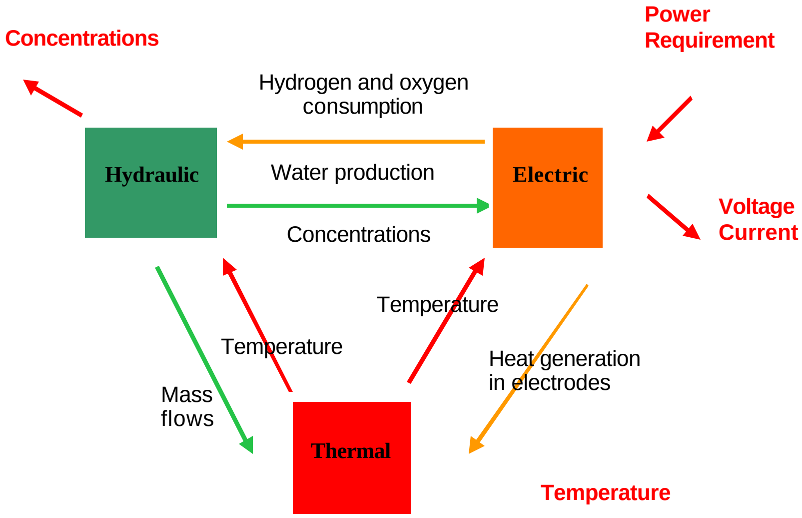

Fig. 4: Stack submodule interaction

With the aid of mathematical simulation the scale of necessary experimentation can be substantially reduced. For the new design of details like anode and cathode chamber CFD simulation was used. The model is now verified by comparison with data of laboratory AFC system.

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